EXPERIMENT 18/1901
LE CHATELIER'S PRINCIPLE

INTRODUCTION:

You learned in experiments on equilibrium that many reactions are reversible. You will conduct experiments in the lab in which you will control the reversibility of these reactions.

In this experiment you will study some reactions that are reversible and learn to recognize the relative amount of the reactants and products by observing color changes or the formation of a precipitate. In an aqueous solution the chromate ion, $CrO_4^{-2}(aq)$, can be converted to the dichromate ion, $Cr_2O_7^{-2}(aq)$, and, the $Cr_2O_7^{-2}(aq)$ can be converted to the $CrO_4^{-2}(aq)$ ion. The extent to which these reactions occur is dependent upon the concentration of the hydrogen ion, $H^+(aq)$, in the solution. The $H^+(aq)$ concentration can be increased by adding a source of $H^+(aq)$ -- hydrochloric acid, HCl. The $H^+(aq)$ concentration can be decreased by adding a solution of sodium hydroxide, NaOH, which contains the hydroxide ion, OH^-. The OH^- reacts with the H^+ to form H_2O.

TIMING: This experiment can be completed in one class period. There is no convenient stopping point.

PITFALLS AND CAUTIONS:

1. Spot plates or wells must be scrupulously clean to avoid contamination. Excess hydrogen or hydroxide ions will change the results dramatically.
2. Attempt to answer the questions as you go along, at least while still in the lab. If you get conflicting or doubtful results, repeat the step to verify the results. The teacher will check your understanding.

PROCEDURE:

Part I: the Chromate-dichromate Equilibrium

a. A 0.1M potassium chromate, K_2CrO_4, and a 0.1M potassium dichromate, $K_2Cr_2O_7$, solution will serve as sources for the ions, $CrO_4^{-2}(aq)$ and $Cr_2O_7^{-2}(aq)$. Record the color of each solution.

b. Place 3 drops of each solution into separate test tubes. Add 1M sodium hydroxide, NaOH, alternately to each well one drop at a time. Record the colors observed. Retain the wells for step e.

c. Repeat the procedure of step b with fresh solutions in clean wells, but add 1M hydrochloric acid, HCl, drop by drop alternately to each test tube. Record the colors observed. Retain these wells for step d.

d. Add 1M NaOH, drop by drop, to one of the tubes obtained in step c until a change is noted.

e. Add 1M HCl, drop by drop, to one of the wells obtained in step b until a change is noted.

Part II: Equilibrium Between Solid Barium Chromate, $Bacro_4(s)$, and a Saturated Solution of its Ions

a. Place 2 drops of 0.1M K_2CrO_4 in a clean well. Add 1 drops of 1M NaOH.

b. Place 2 drops of 0.1M $K_2Cr_2O_7$ in a clean test tube. Add 1 drops of 1M HCl.

c. Now add 0.1M barium nitrate, $Ba(NO_3)_2$, alternately, one drop at a time, to each of the above wells until a change is noted. Record your conclusions about the relative solubilities of $BaCrO_4(s)$ and $BaCr_2O_7(s)$. Save these wells for steps d and e.

d. To the solution saved from step c which contained the NaOH add 1M HCl, drop by drop, until a change is noted. Record your observations.

e. To the solution saved from step c which contained the HCl, add 1M NaOH, drop by drop, until a change is noted. Record your observations.

f. Suggest a way to reverse the changes and reactions you observed in step d. Do the same for step e. Try these experiments.

g. Place 2 drops of 0.1M $K_2Cr_2O_7$ in a clean well and the same amount of 0.1M K_2CrO_4 in another clean well. Add 2 drops of 0.1M $Ba(NO_3)_2$ to each. Record your observations.

Part III: Additional Experiments on the Chromate-dichromate Equilibrium

a. Place 2 drops of each solution, 0.1M K_2CrO_4 and 0.1M $K_2Cr_2O_7$, into separate wells. Do this setup for 6 tests.

2. Add 1 or 2 drops of the following chemicals alternately to a sample of 0.1M K_2CrO_4 and 0.1M $K_2Cr_2O_7$ one drop at a time. Record the color changes observed.

3. In the pair of wells #1 use 1M acetic acid, CH_3COOH, in wells #2 use 1M nitric acid, HNO_3; in wells #3 use 1M potassium hydroxide, KOH; in wells #4 use 1M lithium hydroxide, LiOH.

4. In wells #5 use ethyl alcohol, C_2H_5OH, and in wells #6 use 1M ammonia, $NH_3(aq)$.

CALCULATIONS AND RESULTS

PART I:

1. a) How does the chromate-dichromate equilibrium depend on hydrogen ions?

   $CrO_4^{-2} + H^+ \rightarrow Cr_2O_7^{-2} + H_2O$

   Record this reaction on your paper and use arrows to explain your data.

   b) Balance the equation for the chromate-dichromate equilibrium

   c) Use Le Chatelier's Principle to explain the color changes noted in Part I, steps c & e. (Hint: It is easiest to label the color of the chromate ion and the dichromate ion before explaining.)

2. a) How does the chromate-dichromate equilibrium depend on hydroxide ions?

   $Cr_2O_7^{-2} + OH^- \rightarrow CrO_4^{-2} + H_2O$

   Record this reaction on your paper and use arrows to explain your data.

   b) Balance the equation for the dichromate-chromate.

   c) Use Le Chatelier's Principle to explain the color changes noted in Part I, steps b & d.(Hint: It is easiest to label the color of the chromate ion and the dichromate ion before explaining.)

PART II:

1. a) Write the equations for the dissolving of $BaCrO_4$ into its ions.

   b) Using the above equation, those you balanced in calculations 1b) and 2b) of part I, and Le Chatelier's Principle, explain the results you obtained in steps c, d, and e of Part II.

2. From your observations in step g, what can you conclude about the relative equilibrium concentrations of $CrO_4^{-2}(aq)$ ion in **each of the solutions** 0.1M $K_2Cr_2O_7$ and 0.1M K_2CrO_4 <u>before</u> the 0.1M $Ba(NO_3)_2$ solution is added? (Which has more $CrO_4^{-2}(aq)$ ions?)

PART III:

1. a) Make a list of the chemicals in **Part III c** which caused the color to change from that of the $Cr_2O_7^{-2}(aq)$ ion to that of the $CrO_4^{-2}(aq)$ ion?

   b) Make a list of the chemicals in **Part III c** which caused the color to change from that of the $CrO_4^{-2}(aq)$ ion to the $Cr_2O_7^{-2}(aq)$ ion?

2. a) Which ions do the solutions you listed in calculation 1a) have in common? Classify these substances as acid or base.

   b) Which ions do the solutions you listed in calculation 1b) have in common? Classify these substances as acid or base.

3. Give an explanation for the results in **Part III d** when
   a) ethyl alcohol, C_2H_5OH, was added;
   b) the solutions of aqueous ammonia, $NH_3(aq)$, was added.

4. On the basis of your answers to calculation 2, predict two additional substances which might have the same effect on the chromate-dichromate equilibrium as those listed in calculations 1a) and 1b). Classify each substance as acid or base.

Error Analysis:

Conclusions: